

amplifier **175** is sent to controller **150** via the TOUCH_SIGNAL signal shown in FIG. 7. A similar circuit (not shown), used for PDs arranged along the other edge of touch screen **100**, processes current from a selected row PD, and sends the output current to controller **150** via one of the PD_ROW_n signals shown in FIG. 7. In this embodiment, the remaining PD_ROW and PD_COL signals are not used. Additional filter and amplifier circuits are used when PDs along one edge are grouped into subgroups as described above with respect to the second PD receiver configuration. In this case additional PD_ROW and PD_COL signals are used as required by the number of ADC inputs to controller **150**.

[0156] The circuit shown in FIG. 23A includes two filter and amplifier paths. One path ends at TOUCH_SIGNAL in the middle of FIG. 23A, and another path, which performs a second filter and amplification, ends at TOUCH_SIGNAL_2 at the right of FIG. 23A. In one embodiment of the present invention, both outputs TOUCH_SIGNAL and TOUCH_SIGNAL_2 are connected to controller **150**, and firmware running on controller **150** is used to select one of the two signals. In another embodiment of the present invention, only one of the outputs is connected to controller **150**.

[0157] Signal filter and amplifier **175** includes passive sub-circuits that have two resistors, such as resistors R10 and R11, and one capacitor, such as capacitor C10. Resistors such as R12 and R13 are pass-through zero-ohm resistors.

[0158] PD_COL connects with the ADC input via resistors R10, R12, R13 and R14, and via capacitors C10 and C11. According to an embodiment of the present invention, capacitor C11 is a zero-ohm capacitor. The signal level is set by resistor R13 and capacitor C1. R13 sets the voltage amplitude range entering the ADC, and C1 integrates the current to generate voltage input to the ADC. According to this configuration, the signal does not have to be biased to within a predetermined range, such as between V and VCC, because open collectors are used to read the active PD output value. It is noted in FIG. 23A that the signal is in the range of +3V and below.

[0159] An alternative signal filter and amplifier circuit is shown in FIG. 23B, in accordance with an embodiment of the present invention. In this embodiment, an OP amplifier acts like a low impedance current to a voltage amplifier; i.e., a trans-impedance. This configuration results in less sensitivity to capacitance and truer current sensing. For this embodiment, the relationship between light and current is substantially linear.

[0160] Referring to FIG. 23B, signal filter and amplifier **175** receives as input the output current from a selected column PD, denoted PD_COL. The output current of signal filter and amplifier **175** is sent to controller **150** via the TOUCH_SIGNAL signal shown in FIG. 7. A similar circuit (not shown), used for PDs arranged along the other edge of touch screen **100**, processes current from a selected row PD, and sends the output current to controller **150** via the TOUCH_SIGNAL_2 signal shown in FIG. 7.

[0161] This embodiment uses a large phase margin in order to eliminate high amplification grade that causes the amplifier to oscillate.

[0162] The discrete transistor amplifier circuits of FIG. 23A are of advantage in having high frequency response and low cost. However, they are of disadvantage in having non-linear integration over time.

[0163] A feature of the discrete transistor amplifier circuits of FIG. 23A is that DC amplification is reduced, and the PD

receiver may thus be made entirely AC current. However, problems may arise when shifting between PDs having a large signal difference between them. E.g., suppose a first PD receives little light and is amplified by the transistor-based amplifier to be within a designated range, and a second PD receives substantially more light, based on its position relative to ambient light sources. Then the transistor-based amplifier, having greatly amplified the first signal, will also greatly amplify the second AC signal, and also the rising edge of the difference between signals, including the second signal DC values. The combination of these amplified DC values, together with the AC of the second PD, may amplify the resulting signal beyond the maximum voltage, say, 3V.

2. Optics of Touch Screen **100**

[0164] Reference is now made to FIG. 24, which is a diagram of a prior art lens assembly for an LED and PD.

[0165] Reference is now made to FIGS. 25A, which is a diagram of a lens assembly for use with LEDs and PDs for a touch screen, in accordance with an embodiment of the present invention. Shown in FIG. 25A are four optical surfaces for the LED lens side, and four optical surfaces for the PD side. The focal length, f , is not necessarily the same as the distance from the LED to the last lens surface, LENS SURFACE 2. It may be larger or smaller than such distance. If the focal length is smaller than such distance, then the light spreads over a larger receiving area, and the receiving side scans a larger area and thus receives more background light. Nevertheless, there is an advantage to having a focal length slightly smaller than the distance from the LED to the last lens surface, because an optimized design is able to sense for tolerances of the optical elements.

[0166] Reference is now made to in FIG. 25B, which is a diagram of a lens assembly for distributing two groups of light beams, denote by X and Y, in accordance with an embodiment of the present invention. Shown in FIG. 25B is a lens assembly aligned substantially parallel with the surface of the touch screen, and a second lens assembly skewed at an angle with the surface of the touch screen. The second lens assembly is arranged so that a finger or stylus positioned near the touch screen, reflects some or all of light beams Y to the PD receivers.

[0167] It will be appreciated by those skilled in the art that although FIGS. 25A and 25B illustrate convex lenses, concave and/or convex lenses may be used to achieve the dual foci.

[0168] The lens assembly shown in FIG. 25A is designed with the following objectives:

[0169] as much as possible of the LED light arrives at the PD;

[0170] as little as possible of the sounding background light arrives at the PD;

[0171] the horizontal components of the light beams should be as wide as the distance between LEDs, which improves performance in interpolating position between light beams; and

[0172] the vertical components of the light beams are limited by the height of a frame over the LCD screen.

[0173] Reference is now made to FIGS. 26A and 26B, which are diagrams of simplified lens assemblies corresponding to the respective lens assemblies of FIGS. 25A and 25B, in accordance with an embodiment of the present invention. The simplified lens assembly in FIG. 26A resembles that of a camera lens, and is useful for determining LED and PD die